F. Langley Research Center (LaRC)

The LaRC Small UAS (sUAS) Range Safety Office's sUAS Operations Working Group, which began in 2011, continued to expand and develop during FY 2012. The genesis of the sUAS Operations Working Group was to implement and coordinate consolidation activities in terms of sharing common recourses, providing pilot and observer training, and integrating operations policy requirements from Headquarters, the Center, and other organizations including the FAA, DoD, and the Department of Homeland Security (DHS). The sUAS Operations Working Group was chartered with membership from all UAS operational labs and projects at LaRC flying in the National Airspace (NAS) or restricted airspace. The goal is to ensure compliance with governing policies, processes, procedures, and reviews of the ever-growing UA infrastructure.

All sUAS projects at LaRC are governed by the NASA LaRC Langley Policy Requirements document LPR 1710.16, Aviation Operation Safety Manual. Also contained within this document are the Range Safety Requirements tailored for the unique needs of the Center in order to meet compliance under the requirements of the NPR 8715.5, NASA Range Safety Program.

1. LaRC Range Safety and sUAS Operation Oversight

LaRC Range Safety Office provided oversight for sUAS fight operations in both the NAS and in Restricted Air Space in 2012. NASA LaRC Range Safety continued to work closely with the FAA's UAS Program Office and with the respective organizations that manage Restricted Air Space. The primary goal of this effort was twofold: 1) to maintain safety of flight for the public, public property, and test personnel, and 2) to ensure that NASA Range Safety requirements were in alignment with NPR 8715.5, NASA Range Fight Safety Program. LaRC currently maintains Certificate of Authorizations (COAs) to fly in the NAS at Allen C. Parkinson (Fort Pickett Army Airfield Blackstone) and at 31VA Aberdeen, Smithfield, Virginia.

This year, LaRC acquired a new COA at 42VA Virginia Beach at the Military Aviation Museum in support of the NASA integration in the NAS program. A working group assigned by the ExCom, (Executive Committee members representing NASA, DoD, DHS, and the FAA) Senior Steering Group, focused on streamlining access to class G airspace. With that assignment, the following issue was addressed:

> "ExCom agencies need to be able to conduct day and night operations with small (55 pounds or less) UAS in Class G airspace at specifically identified locations and boundaries (outside of 5 NM of a military or public-use airport, heliport or seaplane base) using notification and other appropriate airspace de-confliction procedures."

This activity included flight demonstrations in the NAS in both day and night operation conditions. As part of the process, the working group obtained permission from the FAA (via COA) to fly sUAS in this class G airspace, the Range Safety Office had to obtain permission to use the privately owned airfield at 42VA on a non-interference bases, and the RSO had to complete the required Range Safety Hazards Analysis in order to comply with NASA's Range Safety Program. It is anticipated that a memorandum of agreement will be signed between NASA and FAA Headquarters providing a new notification process for obtaining access to class G airspace in the NAS within the near future.

The Range Safety Office also supported several deployments to Finnegan UAS Air Field at Fort A. P. Hill, Virginia (operations in Restricted Air Space) and at the US Navy Webster Air Field, Maryland. A total of 47 deployment days were logged across these facilities that included requirements for UAS pilot flight training / proficiency and for programmatic experimental flight research support.

The RSO at NASA LaRC was able to complete JARSS training provided by the Millennium Engineering & Integration Company in March of 2012. As a result, this mission planning and risk mitigation tool was applied to the work that was completed later in the year in support of the access to class G airspace activity and the completion of the Range Safety Hazards Analysis report for UAS operation at 42VA, Virginia Beach.

2. FY 2012 sUAS Flight Projects

a. Airborne Subscale Transport Aircraft Research (AirSTAR) project

The AirSTAR project began working on Phase V of the project. The AirSTAR test facility consists of a Mobile Operations Station (MOS) and a new experimental test-bed called a BAT-4, shown in Figure 36. The BAT-4 is currently being flown by an external pilot at 31VA in the NAS within visual line-of-sight for the purpose of initial checkout of the vehicle, flight control, and propulsion systems. The BAT-4 will be used as a low-cost test-bed for evaluating the Phase V CONOPS, on-board avionics, flight controls, navigation, and FTS systems.

FIGURE 36: AIRSTAR BAT-4 EXPERIMENTAL TEST-BED BEING FLOWN BY AN EXTERNAL PILOT IN RC MODE WITHIN VISUAL LINE OF SIGHT

The Phase V CONOPS will be flown by a remote internal pilot stationed inside the MOS as shown in Figure 37. Figure 37 shows the IP and glass cockpit set up inside the MOS. Should an off nominal event occur, the Range Safety Officer will have Flight Termination Authority in the event that the on-board autopilot fails to return the vehicle to a “home waypoint.” The RSO is working with the project to help define and implement failsafe and FTS requirements.

FIGURE 37: AIRSTAR REMOTE INTERNAL PILOT AND GLASS COCKPIT CONFIGURATION LOCATED INSIDE THE MOS

b. AirSTAR Beyond Visual Range CONOPS

The AirSTAR Beyond Visual Range (BVR) flight system is designed to enable operations of up to 10 miles and 15,000 foot distances from the MOS. Primarily, this capability is intended to support larger aircraft and more complex research maneuvers that cannot be supported in the current "within visual range" operations. The visual range requirement required by the use of an external pilot restricts the size of the test range (both ground distance and altitude) and, as a result, restricts the aircraft size. Research quality is also affected due to the more restricted operations area in order to keep the aircraft within visual range of the external pilot. The restricted hazard area currently causes 50 percent of flight time to be spent in turns to remain within the hazard area, and causes research to be restricted to maneuvers capable of being complete in the 20-second window it takes the aircraft to traverse a straight-leg in the flight pattern.

The general AirSTAR BVR system CONOPS are as follows as illustrated in Figure 38:

1. Remote Pilot (MOS pilot) performs conventional take-off
2. System checks performed during initial climb to research altitude
3. Remote Pilot executes the flight test plan
4. Operational area is within 10 miles and 15,000 feet
5. Remote Pilot returns to runway and performs conventional landing
6. Total flight time is approximately 1 hour

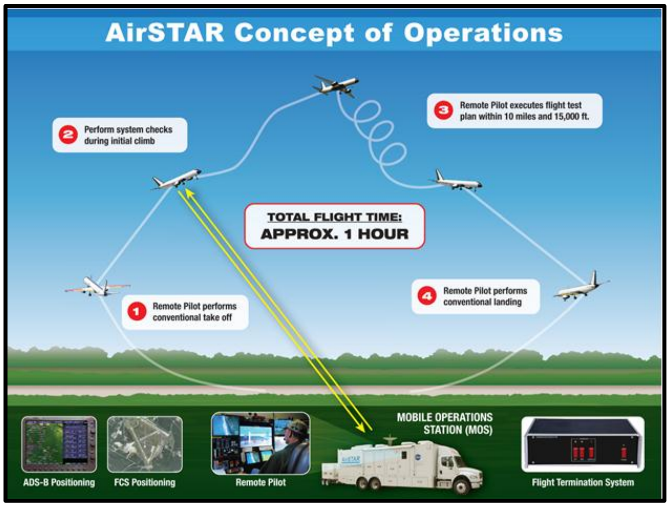

FIGURE 38: AIRSTAR REMOTE INTERNAL PILOT AND CONOPS FOR BEYOND VISUAL RANGE (BVR) OF SIGHT RESEARCH OPERATIONS

AirSTAR BVR contingency systems consist of the following:

1. ADS-B system to provide redundant positioning information that is independent of the flight computer system.

2. Onboard autopilot is capable of taking over flight of the aircraft and returning aircraft to holding pattern in the case of lost telemetry and command and control link. Autopilot is also capable of auto-landing capability (though this may not be initially supported by the AirSTAR system).

3. Flight Termination System is capable of forcing the aircraft down within a certain ground range of its current position when commanded from inside the MOS. The FTS utilizes forced surface positions to force the aircraft to the ground.

c. Automated Flight Control Lab

The Automated Flight Control Lab conducted UAS flights during the July and August time period in support of developing a memorandum of agreement between the FAA and several agencies (NASA, DoD, and DHS) that would provide both day and night access to class G airspace for UASs under 55 pounds. The culmination of this effort resulted in two successful flight demonstrations requested by the FAA and DoD in class G airspace: day operations conducted at the Virginia Military Aviation Museum (42VA, Virginia Beach) on September 5, and night operations conducted at Aberdeen airfield in Smithfield (31VA) on September 11.

Proven automated Flight Control Test-beds (FLiC) were outfitted with navigational lights and anti-collision strobes to provide nighttime visual orientation. Initial flights were conducted in restricted airspace at Fort A.P. Hill, where the lighting configuration was clearly visible at typical visual range distances up to a half mile in both twilight and night darkness. Takeoff roll and rotation were performed manually and the autopilot was engaged at approximately 50 feet above ground level. Commands from the ground station were issued to have the autopilot execute return to home, approach, and landing patterns as well as adjustments to altitude and airspeed. Final runway alignment, landing flare, and rollout were performed manually.

Dr. Mark A. Motter provided technical direction for the required modifications to the FLiC and was the external pilot for both day and night operations. Figure 39 shows Mark preparing the FLiC test-bed for one of the flights at 31VA as sunset conditions approach. James High provided logistical support and was the ground station operator shown in Figure 40 which also shows the vehicle back taxi upon completion of a successful autopilot night fight after sunset.

FIGURE 39: FLIGHT CONTROL TEST-BED (FLIC) BEING PREPARED FOR NIGHT FLIGHT DEMONSTRATION AT 31VA IN THE NAS

The development of the experimental FLiC test-bed was supported by various funded projects at the Center and continues currently under the Center Innovation Fund (CIF) for Neuromorphic UAS collision avoidance. All of the automated flights for this effort were conducted on a test-bed flown at the 2005 AUVSI UAV Demo, still in service after several hundred flights.

FIGURE 40: GROUND STATION OPERATOR (LEFT) MONITORS FLIC POSITION IN FLIGHT AND VEHICLE ON RUNWAY (RIGHT) DURING BACK TAXI AFTER A SUCCESSFUL NIGHT FLIGHT OPERATION

d. Small Unmanned Aircraft Vehicle Laboratory (SUAVeLab)

SUAVeLab at NASA Langley is performing research funded by the government to develop the technologies required to combine 2 opposing characteristics into a single UAS vehicle: achieving 24 hour endurance while also achieving Vertical Takeoff and Landing (VTOL) capability. Existing UAS rotorcraft achieve Lift to Drag (L/D) ratios of about 4, which is an effective measurement of aerodynamic efficiency. The SUAVeLab research will achieve an L/D of about 20, so a five-fold improvement in L/D is the key research goal with secondary goals being VTOL and ultra-low community noise. The project performs spiral development of competing concepts through analysis and prototyping of sub-scale demonstration models. Subsequently, the most robust transitioning/controllable vehicle is being developed at full-scale to validate all flight technologies.

Test flights for three concept UAS configurations were conducted over a period of three one-week deployments in restricted airspace at Fort A. P. Hill, Virginia. Figure 41 was taken during one of the deployments and shows the three concept vehicles that were test flown along with the research team of NASA engineers, contractors, and summer college students. Testing is expected to continue through FY13.

FIGURE 41: SUAVELAB RESEARCH TEAM WITH THREE TEST BED CONCEPTS THAT WERE FLIGHT TESTED AT FT. A. P. HILL, VIRGINIA

e. Solar Power Airship

A flight safety hazards analysis was evaluated for a solar powered unmanned airship for both indoor and outdoor flight testing. The airship (Figure 42) was designed and built at NASA LaRC for the purpose of demonstrating solar power (Figure 43) as an alternative green energy source for larger unmanned solar powered UAS for possible use in the future. The first flight test was made on October 13, 2011, and the final demonstration flight was made on October 26, 2012 (Figure 44) with NASA Langley and Department of Transportation staffs. Indoor flight tests were made at a large hangar on LaRC. During the indoor flight test, four batteries were used to power up the airship. For the outdoor test, batteries were completely removed and the airship was powered by sunlight only as it was attached to its tie down structure (seen in Figure 45). Outdoor free-flight of the airship did not occur because the wind conditions (speed and direction) were not within the set boundaries. Nevertheless, all the important factors such as total propulsion thrust, power delivery and consumption from the direct sunlight, 10 degree vector propulsion control, and avionics were measured under the direct sunlight in a tethered airship control mode outside of the hangar.

The airship was designed to have a single helium envelope consisting of two cylindrical components separated by a middle section. Such a configuration offers more lift than the conventional (cigar-shaped) design while still featuring a slender, aerodynamic shape. It also offers more surface area for the solar cells and the gondola for supporting eight cargo containers. The airship was also designed to have neutral buoyancy with payload (cargo containers). The dimensions were determined by calculating the lift for the envisioned configuration. The lift was calculated with consideration for the:

1. Number and size of solar cells and wiring to power the motors for propulsion

2. Design and materials for the gondola with propulsion motors

3. Weight of the eight cargo containers

4. Surface area (weight) of the helium envelope

5. Weight of fins, tie-down bridle straps, and suspended tethers

FIGURE 42: AIRSHIP CONFIGURATION AND DIMENSIONS.

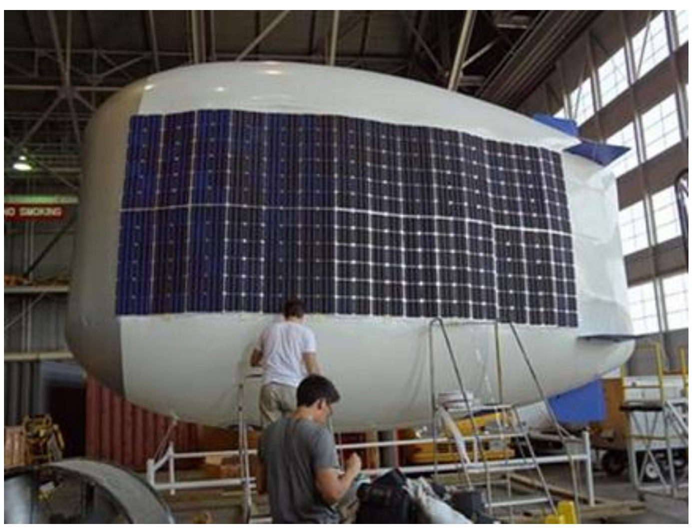

FIGURE 43: PICTURE OF THE 12-CELL SOLAR PANELS BEING ATTACHED TO THE POLYURETHANE ENVELOPE WITH HOOK AND LOOP STRIPS

FIGURE 44: VIDEO SCENE OF THE INDOOR FLIGHT TEST OF THE SOLAR AIRSHIP

FIGURE 45: FULLY ASSEMBLED SOLAR AIRSHIP WAITING FOR FLIGHT TEST SECURED TO TIE DOWN STRUCTURE

f. Rapid Evaluation Concept Lab (REC Lab)

The REC Lab is utilizing an all-electric Edge 540T 33 percent subscale as sUAS research vehicle test-bed (Figure 46). It has a wing span of 8 feet and a nose to tail length of 8 feet. It is built from an off-the-shelf mid-wing aerobatic radio controlled model kit. Its nose mounted, single 26"x10" propeller develops a maximum of 35 pounds of thrust. The propeller is driven by dual tandem electric motors powered by four 5500 mAh lithium polymer batteries. The sUAV weight is about 46 pounds which includes approximately 12 pounds of research instrumentation.

FIGURE 46: EDGE 540T 33% SUBSCALE VEHICLE BEING FLOWN AT FINNEGAN FIELD, FT. A. P. HILL, VIRGINIA

It is being used to research and test prognostic algorithms for battery health, software health, and air traffic conflict detection and resolution. The follow-on research is to use the prognosis results to feed decision models and algorithms which form the basis of robust on-board flight and mission management systems. This research challenge includes demonstrating the software capability using traffic conflict scenarios to trigger on-board decision events.

Collectively, the Edges have flown nearly 100 successful flights at 31VA Aberdeen in the NAS, and Ft. A. P. Hill, Finnegan Field in restricted airspace. These flights include check flights, tests of battery and software health systems, autopilot test and tuning, ADS-B receiver testing, and software integration tests. A progressively autonomous approach is being used to develop the system and operational expertise to ultimately field multiple vehicles in traffic conflict scenarios and demonstrate on-board prognostics based contingency management.

The Range Safety Office is working with the FAA to obtain a COA which will allow multi-vehicle operations to take place in support of this research effort. Data obtained from these traffic conflict scenarios will be shared with the FAA through the NASA Integration in the NAS Program for developing technologies, processes, and procedures for the decision making efforts focused at full integration of UAS in the NAS by 2015. An additional milestone was achieved this year when the FAA assigned registration “N” numbers to two of these REC Lab sUAS vehicles.